Effects of long-term environmental change on predation rates by piscivorous fishes in Lake Union, Washington.

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Lakes throughout North America have exhibited long-term increases in water temperatures over the last three decades that are likely responses to regional climate warming. We will present evidence that the thermal conditions in the Lake Washington-Lake Union ship canal system have warmed substantially in the last 30 years. These temperature increases are not distributed evenly across seasons but appear to be most pronounced in spring and early summer. We used bioenergetics models that calculate fish metabolic responses to changes in thermal conditions to estimate the likely changes in individual predation rates by common piscivorous fishes in the Lake Washington-Lake Union ship canal system. Our analyses suggest that cumulative annual predation rates of rainbow trout, northern pikeminnow and largemouth bass have increased 15%, 12% and 10%, respectively, from 1973-1996. Our models also predict that most of these increases in annual predation rates have occurred during April, May and June – a period when salmon smolts are migrating through the ship canal system en route to Puget Sound. Thus, restoration efforts that aim to reduce predation rates by resident fishes on migrating juvenile salmon are working against environmentally driven increases in lake thermal conditions that increase metabolic rates of resident predators.

In brief, the figures show the following:

Figure 1 (a) Time series of temperature input to the bioenergetics model of fish metabolism. (b) Shows the change in the # days/year above a certain temperature during this time period. These regressions are all significant ($p<0.05$).

Figure 2. Bioenergetics model estimates of cumulative annual predation rates by individual fish from three species over the time period of continuous temperature records in Lake Union. LMB=largemouth bass, RBT=rainbow trout, NPM=northern pikeminnow. Regressions are all significant ($p<0.05$).

Figure 3. We also estimated the month cumulative consumption by the three fish species. We then regressed monthly consumption versus year for each month of the year in the time series. This figure shows the slope of each of those regressions (with 95% confidence intervals). What we see is that most of the increased predation rates occur during the April-June time period. Not much has changed during the rest of the year. This is especially interesting given that most of the salmon smolts move out through Lake Union in May and June.

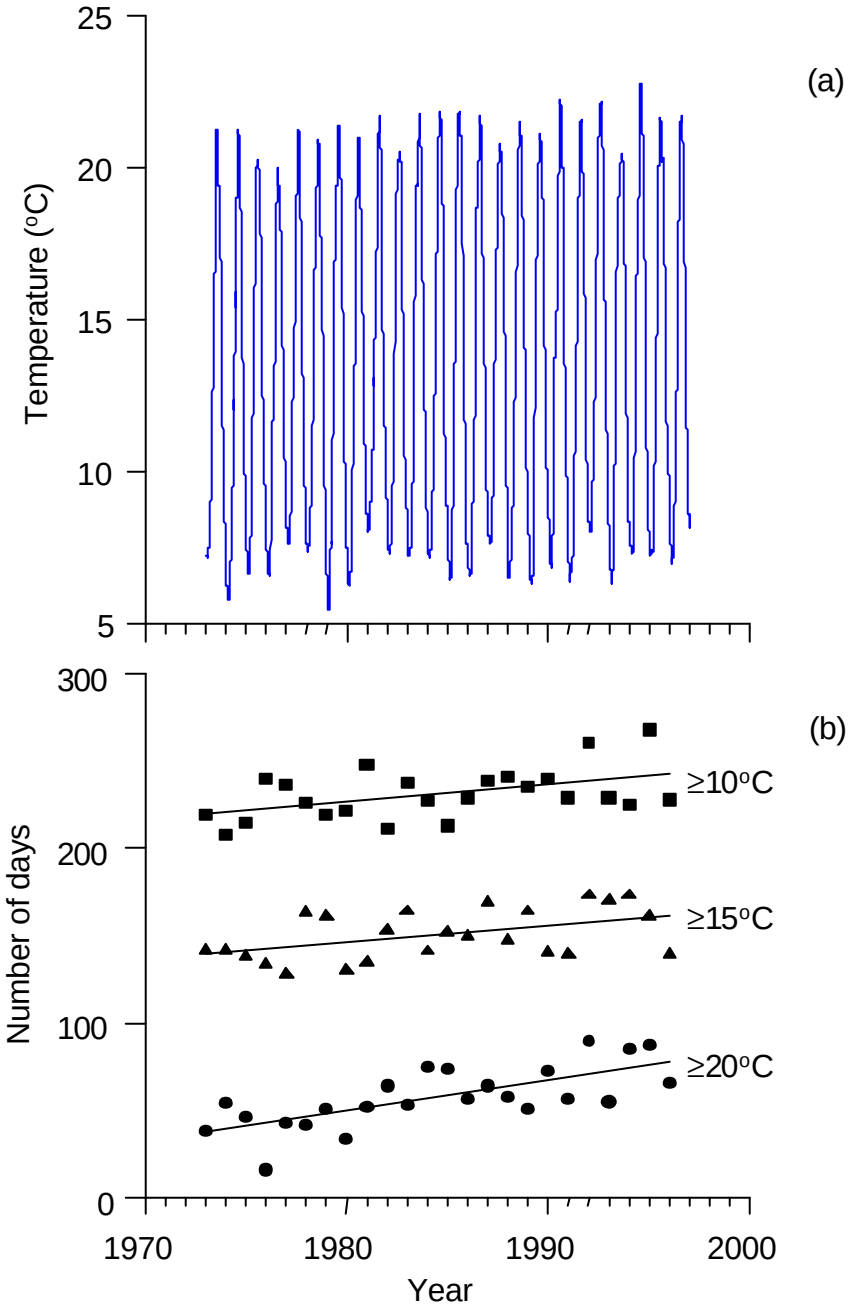
25
20
15
10
5
Temperature (°C)
(a)
300
200
100
0
Number of days
(b)
≥10°C
≥15°C
≥20°C
1970
1980
1990
2000
Year

Figure 1.

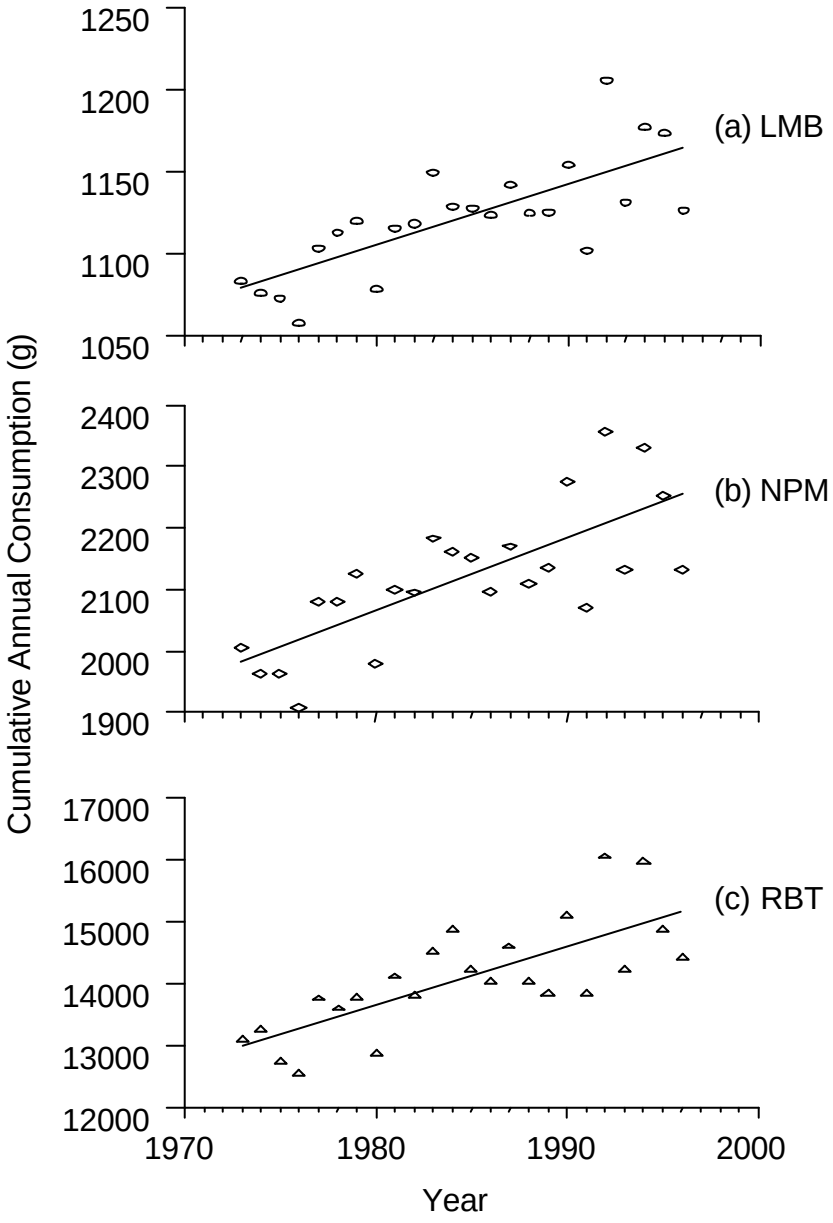
Cumulative Annual Consumption (g)
1250
1200
1150
1100
1050
(a) LMB
2400
2300
2200
2100
2000
1900
(b) NPM
17000
16000
15000
14000
13000
12000
(c) RBT
1970
1980
1990
2000
Year

Figure 2.

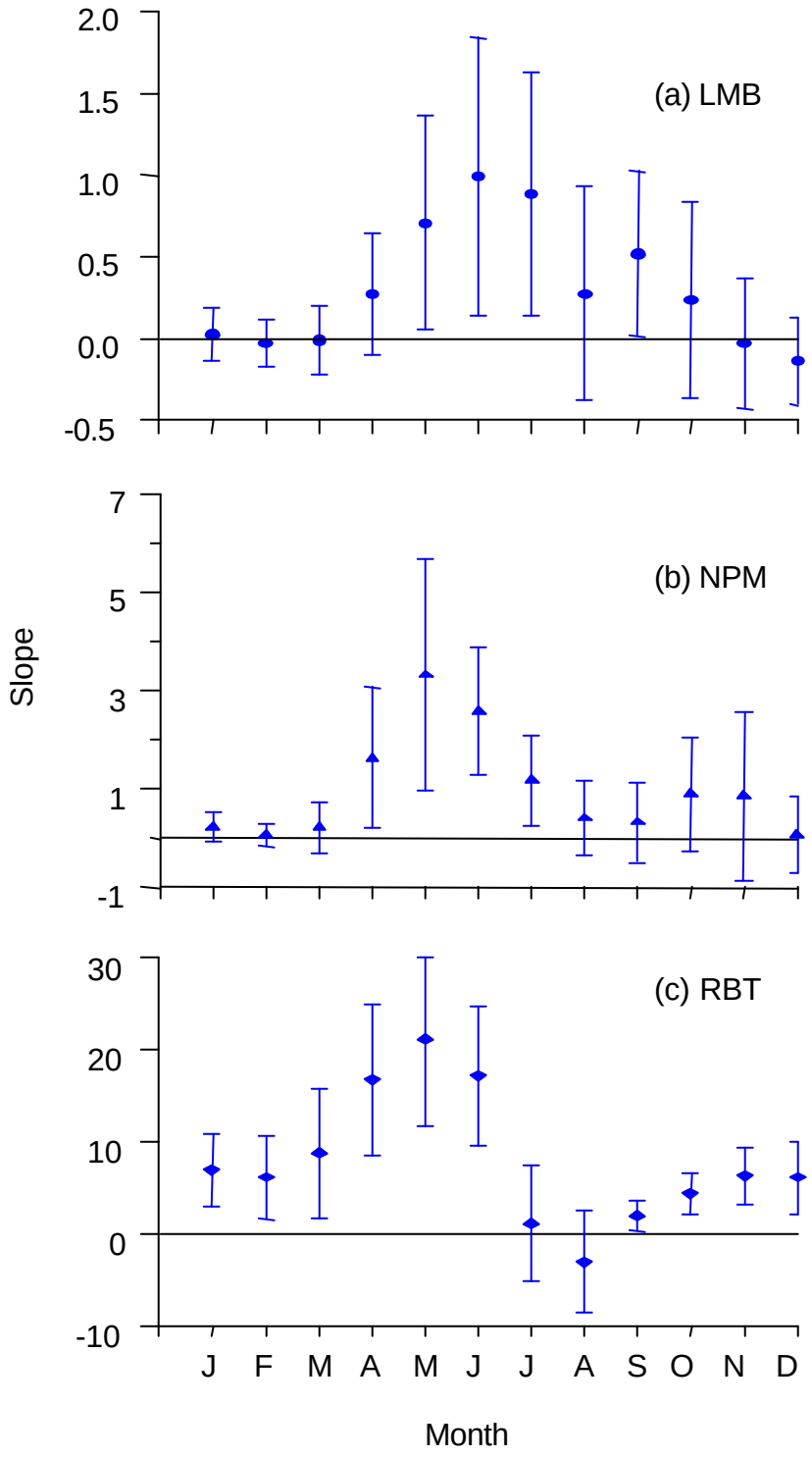
(a) LMB
2.0
1.5
1.0
0.5
0.0
-0.5
(b) NPM
7
5
3
1
-1
Slope
(c) RBT
30
20
10
0
-10
J F M A M J J A S O N D
Month

Figure 3.